

Effect of sowing date of triticale on seasonal herbage production in the central Appalachian Highlands of the United States

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Abstract

Triticale (*X Triticosecale* Wittmack) was evaluated as a complementary pasture to buffer those periods when herbage production from mixed perennial pasture is marginal in the central Appalachian Highlands of the United States. Triticale was sown every month from May to October for five consecutive years from 1999 to 2003. Plant population structure and herbage production were evaluated at intervals until May of the year following establishment. Triticale established quickly at all times of sowing except late October. Wet summers resulted in foliar disease and a rapid decline in plant density when triticale was sown in May and June. In contrast, during the relatively dry summer of 1999, triticale stands exhibited minimal decline. Triticale sown in August had a herbage yield of 1580 kg DM ha⁻¹ when harvested in October which was over twice the herbage yield of triticale sown in May, June and July. Average herbage yield in the following April of triticale sown in September was higher (1750 kg DM ha⁻¹) and less variable than herbage yields from other sowing dates. Plant and tiller populations declined throughout the following April but herbage yields in May were high due to stem and seed head development associated with reproductive growth. Incorporating areas of triticale into mixed-species perennial pasture systems could buffer herbage production during hot and dry summer periods as well as during cool periods of late autumn and early spring.

Keywords: triticale, mixed pasture, summer drought, forage yield, extended grazing season

Introduction

Systems for grazing livestock in the central Appalachian Highlands of the United States rely on herbage production from pastures composed of mixed perennial, cool-season grass and legume species. The productivity of these pastures is affected by grazing and trampling, drought and foliar diseases (Tainton *et al.*, 1996). Seasonal variation in the herbage production and nutritive value of mixed cool-season grass pastures has been extensively reviewed (Nelson and Volenec, 1995; Sheath and Clark, 1996; Vallentine, 2001). The interaction of seasonal weather patterns and plant developmental characteristics is largely responsible for the observed trends in herbage production and nutritive value. The climate of the central Appalachian Highlands is typified by cold winters (mean January temperatures below 0°C), warm summers (June, July and August mean temperatures near 20°C) and relatively uniform precipitation throughout the year. The area falls within the Dfa zone of the Koppen-Geiger climate classification system (Peel *et al.*, 2007). Herbage growth begins typically in early spring in response to increasing temperatures. Growth rates reach an annual peak in mid- to late spring, are lower during hot, dry periods during summer and may recover during the cooler, early- to mid-autumn season if adequate rainfall occurs. Growth rates decline again during mid- to late autumn as lower temperatures induce winter dormancy in the pasture species.

Since grazing is often less expensive than feeding hay or other conserved feeds, increasing the number of days on pasture is considered a cost-effective approach to livestock management. A number of management strategies are used to extend the grazing season and improve the seasonal distribution of herbage mass. These strategies attempt to buffer the impacts of low herbage production due to biotic or abiotic factors. Maintaining herbage *in situ* in the south-eastern USA can provide herbage of high nutritive value for winter grazing (Riesterer *et al.*, 2000). Small-grain species are

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used routinely in many areas to extend the grazing season during spring, autumn and winter and to complement established mixed pastures (Mccoloy *et al.*, 1971; Brown and Almodares, 1976; Juskiw *et al.*, 1999). Although there are costs associated with sowing annual species, spring-sown winter annuals establish readily, and the distribution of the herbage yield of spring-sown winter annuals can provide grazing during the period from mid-June to early September, when herbage growth is low under drought conditions (Aasen and Baron, 1993; Foster, 2004), and late into the autumn (Jedel and Salmon, 1995). Triticale (*X Triticosecale* Wittmack) has excellent drought tolerance and, once established, equals or exceeds winter wheat in cold hardiness (Briggs, 2005). In this study, winter triticale was evaluated as a potential component of grazing systems due to triticale's tolerance of low temperatures in winter and drought in summer that are common features in the region. Triticale was evaluated in plots sown at monthly intervals with triticale throughout the growing season over a 5-year period. Clapham *et al.* (2008) summarized yields of herbage of triticale across all years of the study from the perspective of a risk analysis and reported the probabilities of success or failure of triticale and mixed pasture stands achieving specific herbage yields. The objectives of this companion study were to examine the interactions among sowing date and variations in weather between years on the dynamics of plant populations and on herbage production of triticale.

Materials and methods

Experimental treatments and measurements

The research site was located in the south-central portion of the Appalachian Plateau Physiographic Province, herein referred to as the central Appalachian Highlands. This region of dissected topography is underlain by horizontal beds of sedimentary rock from the Mississippian and Pennsylvanian Periods. Elevations generally range from approximately 750 to 1100 m asl. The study was conducted on gently sloping Gilpin series soils (fine-loamy, mixed, active, mesic Typic Hapludults; pH 6.1) in southern West Virginia (38°47'N; 81°58'W). The hilltop site had an elevation of 880 m. The field had been used previously as a hay meadow and pasture and was vegetated with a naturalized mixture of cool season grasses, predominantly cocksfoot (*Dactylis glomerata* L.), tall fescue (*Festuca arundinaceum* Shreb.) and smooth meadow grass (*Poa pratensis* L.), white clover (*Trifolium repens* L.) and a variety of broad-leaved plants including plantains (*Plantago* spp.) and dandelion (*Taraxacum officinale* G.H. Weber ex Wiggers).

Plots of triticale were sown monthly from late May to October each year from 1999 to 2003 (Table 1). Plots were arranged in a randomized complete block design incorporating the monthly triticale sowings within each of four blocks. Each year a new set of plots was established in a new location within the field so that triticale was consistently sown on ground that was freshly converted from the perennial vegetation. Treatments were re-randomized within each block each year. Four to 6 weeks prior to each sowing date, four 3 m × 3 m plots (replicates) were sprayed with glyphosate to kill existing vegetation. The plots were rotary-tilled to a depth of 15 cm and manually smoothed with a garden rake immediately prior to sowing. A small-plot cone seeder (Almaco Inc., Nevada, IA, USA) was used to drill the triticale seed (cv. Trical 102, Resource Seeds Inc., Gilroy, CA, USA) in rows 15 cm apart at a rate of 186 kg live seed ha⁻¹.

The timing and amount of fertilizer applied varied with each sowing date. A compound 10-20-20 fertilizer, applied at rates to provide 33.6 kg N, 67.2 kg P₂O₅ and 67.2 kg K₂O ha⁻¹, was incorporated into the soil when each plot was sown. Additional N in the form of ammonium nitrate was broadcast at a rate of 33.6 kg N ha⁻¹ after each harvest with the exception of the October harvests when no fertilizer was applied. In mid-March of the following year, a compound 10-20-20 fertilizer was broadcast on all plots at rates to provide 33.6 kg N, 67.2 kg P₂O₅ and 67.2 kg K₂O ha⁻¹. Ammonium nitrate was broadcast at a rate of 33.6 kg N ha⁻¹ on all plots after the April harvest. This schedule resulted in all plots receiving totals of 134.4 kg P₂O₅ and 134.4 kg K₂O ha⁻¹. Total N fertilizer varied from 201.6 kg ha⁻¹ for the May-sown plots to 100.8 kg ha⁻¹ for the September- and October-sown plots.

Dry matter (DM) yields of the first harvest after sowing were taken 6–7 weeks following sowing with DM yields of subsequent harvests measured at 4-weekly intervals until October (Table 2). Plots sown in May, June, July and August were harvested four times, three times, twice and once, respectively, in the year of sowing and twice in the spring of the following year (Table 2). Plots, sown in September and October, were harvested only in the spring of the year following sowing. Vegetative growth, occurring during late winter and early spring, was harvested in early April. Flowering stems of triticale began elongating by mid-April of each year and this growth was harvested at the boot stage at the final harvest in early May. Eight plots of triticale were sown in September to allow for two harvest sequences. One set of four replicates was harvested in both the following April and May as described above. The second set of September-sown plots was harvested only once in May to assess the production potential from

Table 1 Dates of sowing of triticale in the months from May to October over the 5 years of the study.

Year	Month of sowing and date					
	May	June	July	August	September	October
1999	26 May	22 June	22 July	18 August	15 September	13 October
2000	26 May	23 June	28 July	21 August	20 September	20 October
2001	30 May	21 June	2 August	21 August	17 September	9 October
2002	24 May	19 June	22 July	21 August	23 September	23 October
2003	27 May	24 June	24 July	21 August	17 September	20 October

Table 2 Dates of harvest in each year at which dry matter yield of herbage of triticale was measured in the 5 years of the study.

Month of harvest	Sowing year and date of harvest				
	1999	2000	2001	2002	2003
July	14 July 1999	10 July 2000	12 July 2001	17 July 2002	14 July 2003
August	11 August 1999	14 August 2000	6 August 2001	14 August 2002	19 August 2003
September	9 September 1999	7 September 2000	6 September 2001	16 September 2002	16 September 2003
October	15 October 1999	16 October 2000	4 October 2001	18 October 2002	21 October 2003
April	6 April 2000	16 April 2001	4 April 2002	3 April 2003	6 April 2004
May	9 May 2000	14 May 2001	9 May 2002	7 May 2003	14 May 2004

a single harvest. The September-sown plots harvested only in May were designated as '1-cut' plots and the September-sown plots cut in both April and May were designated as '2-cut' plots (Table 2).

Dry matter yield at each harvest was determined from a single, permanently marked, 2.1 m strip, centred within each plot and cut to leave a stubble of 6.5 cm. A rotary mower (0.84 m width) was used to harvest herbage that was blown directly into cloth bags from the mower's discharge chute. Dense reproductive growth in spring was clipped with a sickle-bar mower (96 cm width), and then hand-raked and placed into cloth bags. The entire sample from each plot was oven-dried and weighed. After the harvest strips were clipped, the remaining herbage within the plot was clipped and discarded.

Botanical assessments of each plot were conducted prior to each harvest. The botanical composition was determined by averaging the visual assessment of two experienced field personnel. Botanical composition was recorded as cover (the proportion of the sward/plot surface) represented by the following categories: triticale, other grasses, broad-leaved dicotyledonous species and bare ground/dead tissue. Plant densities (plants m⁻²) of triticale were determined following each harvest by counting plants in 2 m of the row (four adjacent, permanently marked, 0.5 m row sections located within the harvest strips). Tiller population (tillers plant⁻¹) of triticale was assessed at irregular intervals throughout the growing and dormant seasons from five permanently

marked plants in each plot. New plants were marked when previously marked plants died.

Statistical analyses

Dry matter yield, plant density and cover of triticale were analysed via analysis of variance using a repeated measures model within the MIXED procedure of SAS (Littell *et al.*, 1996). The main effects of year of sowing, month of sowing and month of harvest and their interactions were evaluated. Year of sowing was considered a fixed effect rather than a random effect in order to evaluate its interactions which were associated with variable yearly weather. Month of harvest was the repeated factor. Replicate within year was considered random. An autoregressive covariance structure was utilized. Significant differences between least square treatment means were evaluated using the Bonferroni adjustment to control the family-wise error rate (Westfall *et al.*, 1999). Due to the irregular intervals of data collection, analysis of data on tiller populations was carried out via analysis of covariance (Littell *et al.*, 2002) using assessment date (coded as the number of days since 1 June in the year of sowing) as the covariate. The analysis provided a determination of the significance of year of sowing, day of assessment and their interaction on tiller population. Some data for the May- and June-sown plots in 2001 were missing due to the loss of the stands following a problem with the application of fertilizer.

Results

Weather conditions

Temperatures reached annual peak values in June, July and August and lowest values occurred in December, January and February (Figure 1). Mean monthly temperature extremes ranged from a high of 22.0°C in July 1999 to a low of -5.4°C in both December 2000 and January 2003. There was little variation from year to year in the seasonal pattern of mean monthly temperatures although temperatures in March in 2000 and 2001, and November in 2000 and 2002, were below the average of the 6 years.

Precipitation varied greatly from year to year for a given month and from month to month for a given year. For instance, precipitation in the month of July ranged from 8.6 cm in 1999 to 26.6 cm in 2001. In 2002, total precipitation of 18.1 cm in July was followed by only 2.4 cm in August. Precipitation from January to May was similar for all years, with a cumulative average of approximately 42 cm by the end of May (Figure 1). Monthly precipitation from May to December of 1999 was relatively constant but at a lower level than the other years reaching a total of only 84 cm for the year. In contrast the period

from May to December in 2003 and 2004 had relatively uniform monthly precipitation averaging 12 cm month⁻¹ that led to high total annual precipitation of approximately 130 cm. The three wettest summer months of the study occurred in July of 2000, 2001 and 2002 with precipitation ranging from 18 to 27 cm month⁻¹. The precipitation in July of 2000 and 2001 was followed by drier months until December, during these periods precipitation averaged only 5.3 and 4.5 cm month⁻¹, respectively.

Dry matter yields

Dry matter yields of triticale are presented in Figure 2. Year of sowing, month of sowing, month of harvest and their interactions were all significant ($P < 0.001$) influences on DM yield.

The first harvest of the May-sown triticale took place in July. These initial yields ranged from 1150 kg DM ha⁻¹ in 2001 to 2750 kg DM ha⁻¹ in 2002. Yields of May-sown triticale declined progressively from the July to October harvests in all years. The decline in DM yield was least in 1999 when precipitation from July to October was low. The higher precipitation in the other years in conjunction with high summer temperatures lead to foliar disease that reduced DM yields of May-sown triticale. June- and July-sown triticale exhibited the same declining trends in DM yield from August to October as those seen in the May-sown plots. In October, average yields ranged widely from 2586 kg DM ha⁻¹ for plots established in August 1999 to <100 kg DM ha⁻¹ for plots established in May 2002.

Dry matter yields in the following spring varied from year to year for the sowing dates. Yields of DM in April of May-, June-, July- and August-sown plots often reflected the DM yield in the previous October. For example, plots established in May 1999 had relatively high average DM yields of 1195 kg ha⁻¹ in October and 1395 kg ha⁻¹ in April, while plots established in May 2000 had relatively low average DM yields of 379 kg ha⁻¹ in October and 539 kg ha⁻¹ in April. These observations reflect the relatively stable plant density and cover over the winter for these plots. Plots sown in September had average DM yields of between 1086 kg ha⁻¹ (2002) and 2393 kg ha⁻¹ (2001) in the following April, the narrowest range in DM yield in April of any of the sowing dates. In contrast, plots sown in October had the widest range in DM yield in the following April with DM yields from 43 kg ha⁻¹ (2003) to 2165 kg ha⁻¹ (1999). Earlier sowing dates in October (on or before 13 October) and relatively mild temperatures in November and December benefited the DM yields in 1999 and 2001 and led to higher yields in the following April.

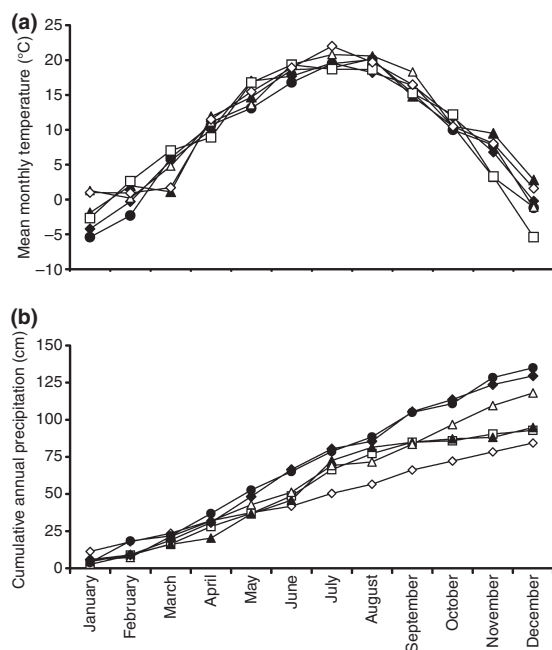


Figure 1 Mean monthly air temperature (a) and cumulative annual precipitation values (b) for the years from 1999 to 2004 at the experimental site in southern West Virginia, USA. Symbols represent the years 1999 (◇), 2000 (□), 2001 (△), 2002 (▽), 2003 (●) and 2004 (◆).

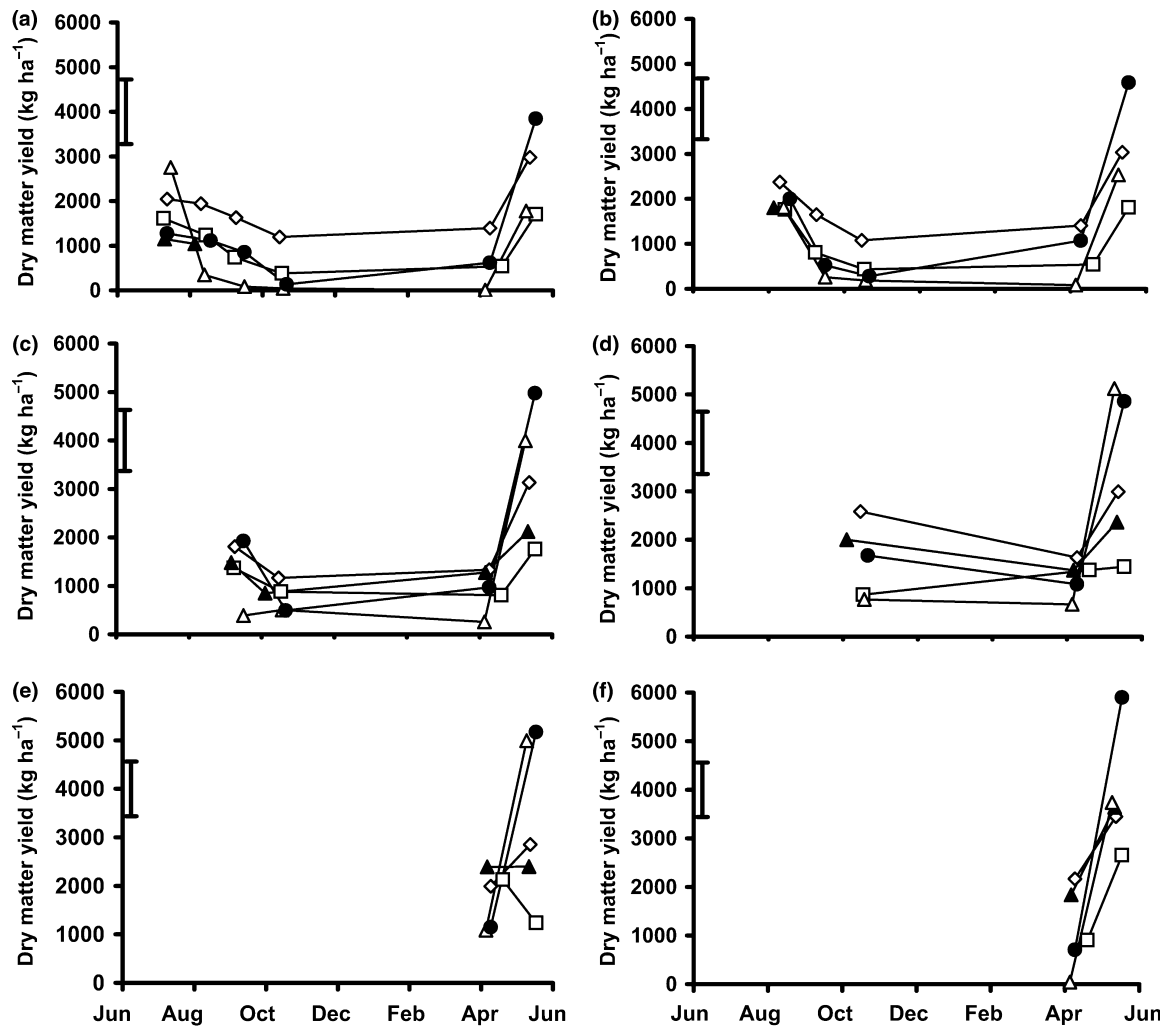


Figure 2 Mean dry matter yields of triticale depicted by month of sowing: (a) May; (b) June; (c) July; (d) August; (e) September and (f) October. Symbols represent the years of sowing: 1999 (\diamond); 2000 (\square); 2001 (\blacktriangle); 2002 (\triangle) and 2003 (\bullet). Error bars depict the maximum calculated Bonferroni adjusted significant difference ($P = 0.05$) among the means for each month of sowing.

Triticale plants grew rapidly throughout late April and early May as stems elongated and reproductive development occurred. Average DM yields in May of '1-cut' September-sown plots ranged from 6412 kg ha⁻¹ (2000) to 8735 kg ha⁻¹ (1999; data not shown). These DM yields exceeded all others in May and illustrate the potential of winter triticale for haylage production. Dry matter yields at the May harvest from plots previously cut one or more times were often over 3000 kg ha⁻¹ although DM yields varied widely among years for all sowing dates. These differences were likely to be due to a number of factors including differing weather patterns in spring, difficulty in harvesting the plots at the same developmental stage

each year, and differences in plant populations associated with previous environmental and harvest regimes. In some cases (i.e. plots established in September 2000) harvests in May were reduced due to removal of some apical meristems of more fully developed plants at the April harvest.

Triticale cover, tiller and plant populations

Triticale emerged quickly and developed into pure or nearly pure stands by the first harvest regardless of sowing date (Figure 3). Year of sowing, month of sowing, month of harvest and their interactions were all significant ($P < 0.001$) factors influencing the cover of

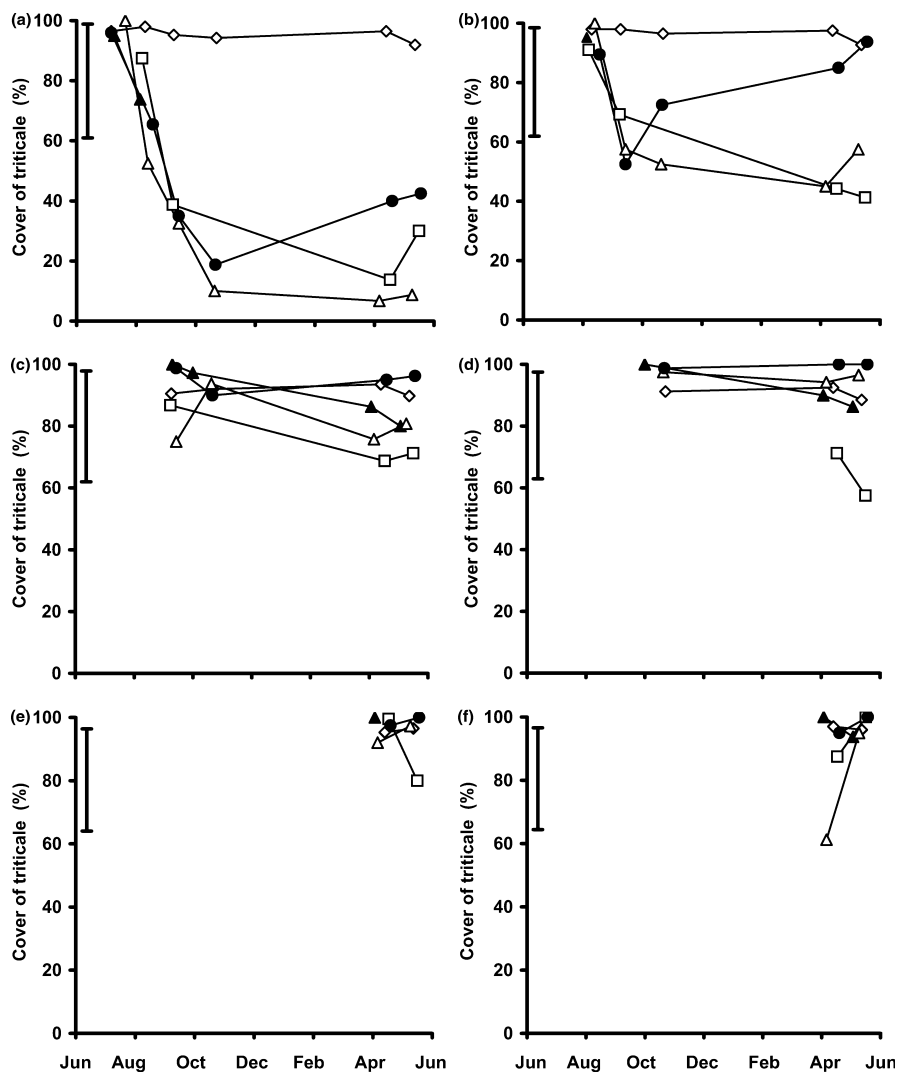


Figure 3 Mean cover estimates of triticale from assessments taken immediately prior to plot harvest are depicted by month of sowing: (a) May; (b) June; (c) July; (d) August; (e) September and (f) October. Symbols represent the years of sowing: 1999 (\diamond); 2000 (\square); 2001 (\blacktriangle); 2002 (\triangle) and 2003 (\bullet). Results for the September 'I cut' treatment are not shown but were above 96% cover each year. Error bars depict the maximum calculated Bonferroni adjusted significant difference ($P = 0.05$) among the means for each month of sowing.

triticale. During the dry growing season in 1999, the May- and June-sown plots maintained a cover of triticale of almost 100%. More often, stands of triticale sown in May and June declined rapidly after the first harvest, especially in wetter years. Loss of plants, coupled with weed encroachment, reduced cover of triticale to less than 40% by the September harvest of May-sown plots in 2000, 2002 and 2003. The decline in cover of June-sown plots in these same years was less severe. Only the June-sown stands in 2003 exhibited increased cover of triticale by the following spring. Variation in triticale cover declined with later sowing

dates. Plots sown in July 2000, 2001 and 2002 exhibited only moderate declines in cover of triticale by the following May. Plots sown in August, September and October generally maintained high covers of triticale until the final harvest in the following May. Plots sown in October 2002, however, had only 60% cover by the following April. Late sowing (Table 1) and cool November temperatures slowed establishment and canopy development of these plots but almost complete cover was achieved by the final May harvest as the sward developed rapidly in response to increasing spring temperatures.

Cover of triticale and DM yield reflected tiller populations (Figure 4) and plant density (Figure 5). For example, consistent DM yields and high triticale cover of the May-sown plots in 1999 were associated with relatively high plant density and tiller populations at each harvest. Rapid declines in cover and yields of May-sown plots from 2000 to 2003 occurred along with declines in plant densities in all four years and in tiller populations in 2001, 2002 and 2003. A positive linear relationship between plant density and cover of triticale was apparent at plant densities below $270 \text{ plants m}^{-2}$ (Figure 6). Above this plant density, cover of triticale was typically sustained near 100%.

Tiller populations of triticale varied depending on year and month of sowing (Figure 4). Tiller populations typically increased in a consistent linear fashion in the first weeks following emergence. In some instances, the linear phase of tiller formation extended until the first

harvest after which tiller populations tended to stabilize (for instance in the August-sown plots in 1999, 2001, 2002 and 2003) or decline (May-, June-, and July-sown plots in 2000). This pattern often included resurgence in tiller numbers in October and November. In some stands, the linear phase of tiller formation lasted only about 4 weeks (i.e. June-sown plots in 2003). Self-shading may have inhibited tiller formation on these plots, which had high plant populations (above $100 \text{ plants m}^{-2}$) and high initial yields ($2004 \text{ kg DM ha}^{-1}$). In contrast, the 1999 and 2001 September-sown stands continued the linear phase of tiller formation for up to 12 and 10 weeks, respectively, reaching populations of up to 16 tillers plant^{-1} during relatively dry autumn periods. The wetter autumns of 2002 and 2003 coincided with September-sown plots reaching populations of less than 6 tillers plant^{-1} . Initial tiller production of October-sown plots was severely reduced by low, mid-

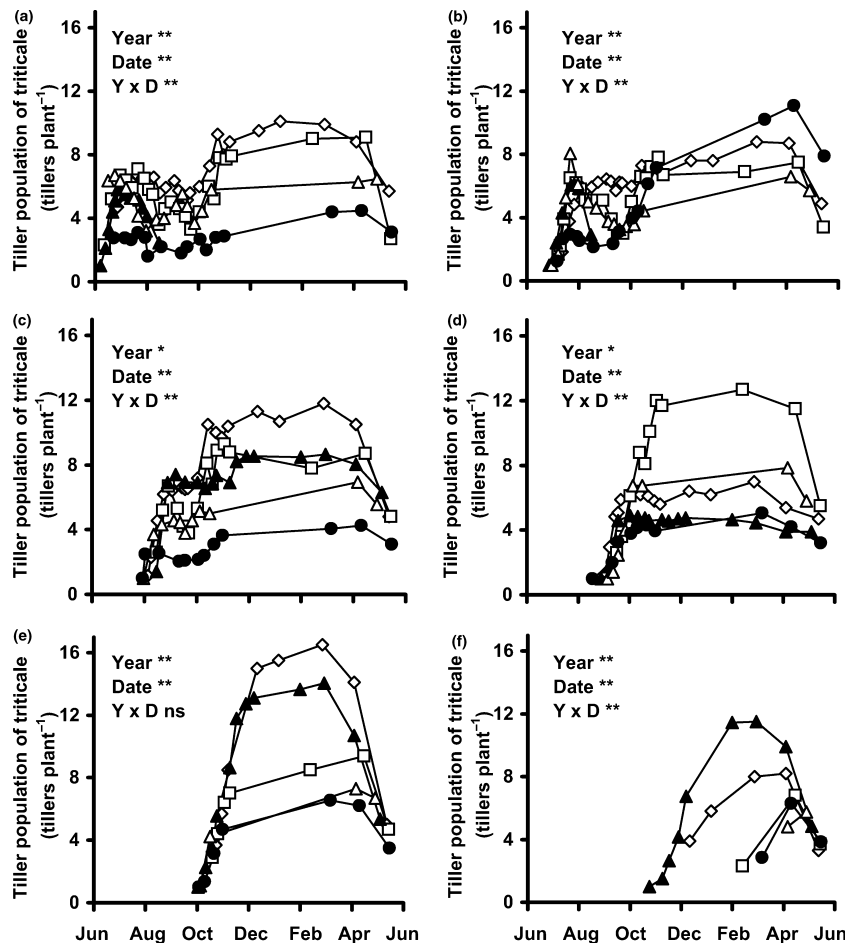


Figure 4 Mean tiller populations of triticale from assessments made at various intervals following establishment are depicted by month of sowing: (a) May; (b) June; (c) July; (d) August; (e) September and (f) October. Symbols represent the years of sowing: 1999 (◇); 2000 (□); 2001 (▲); 2002 (△) and 2003 (●). The symbols *, and ** indicate significance at $P < 0.05$, and 0.01 , respectively.

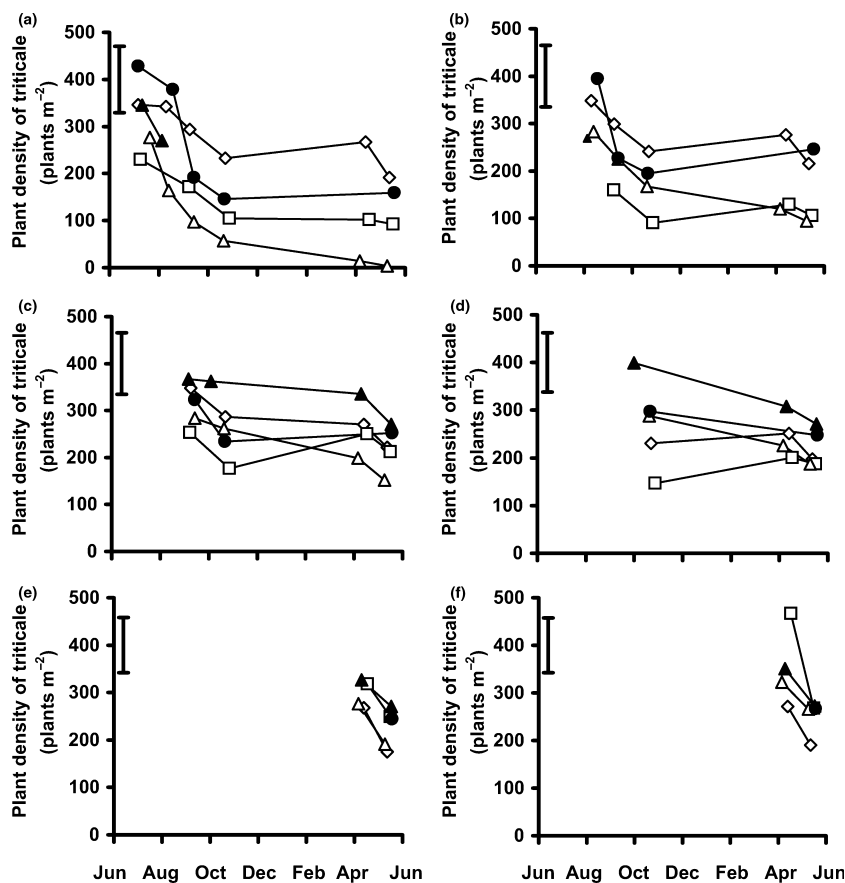


Figure 5 Mean plant density estimates of triticale from assessments made immediately after plot harvest are depicted by month of sowing: (a) May; (b) June; (c) July; (d) August; (e) September and (f) October. Symbols represent the years of sowing: 1999 (\diamond); 2000 (\square); 2001 (\blacktriangle); 2002 (\triangle); and 2003 (\bullet). Error bars depict only the maximum calculated Bonferroni adjusted significant difference ($P = 0.05$) among the means for each month of sowing.

autumn temperatures, especially in 2000, 2002 and 2003 (Figure 4). Tiller populations during winter varied greatly from year to year for all sowing dates. During spring, as plants developed reproductively, sowing dates which resulted in plots with high mid-winter populations tended to lose tillers more rapidly than plots with low mid-winter populations. As a result, the variation in final tiller populations was much reduced by the time of final harvest at boot stage when populations averaged 4.7 tillers plant⁻¹ across all years and sowing months.

Year and month of sowing, month of harvest and their interactions were all significant ($P < 0.001$) influences on plant density (Figure 5). Plant density declined more rapidly in early- than later-sown treatments. This decline was accelerated under the wetter summer conditions of 2002 and 2003. The accelerated decline in plant density during wetter summer conditions resulted in the interaction of year \times harvest being significant. Later sowing dates resulted in a less

dramatic decline in plant density. For example, plant populations remained relatively stable with July and August sowings. Plant densities were relatively stable over the winter period but tended to decline between the April and May harvests as the plants developed reproductively and herbage mass increased.

Discussion

Summer and autumn responses

Fluctuations in rainfall during the growing season were reflected in plant densities and tiller populations per plant, and herbage DM yields of the May- and June-sown plots. Dry summers, such as occurred in 1999, resulted in higher plant densities, tiller populations, cover and DM yield of triticale for May- and June-sown plots relative to wetter summers. Triticale fared poorly in hot and wet conditions which led to foliar disease

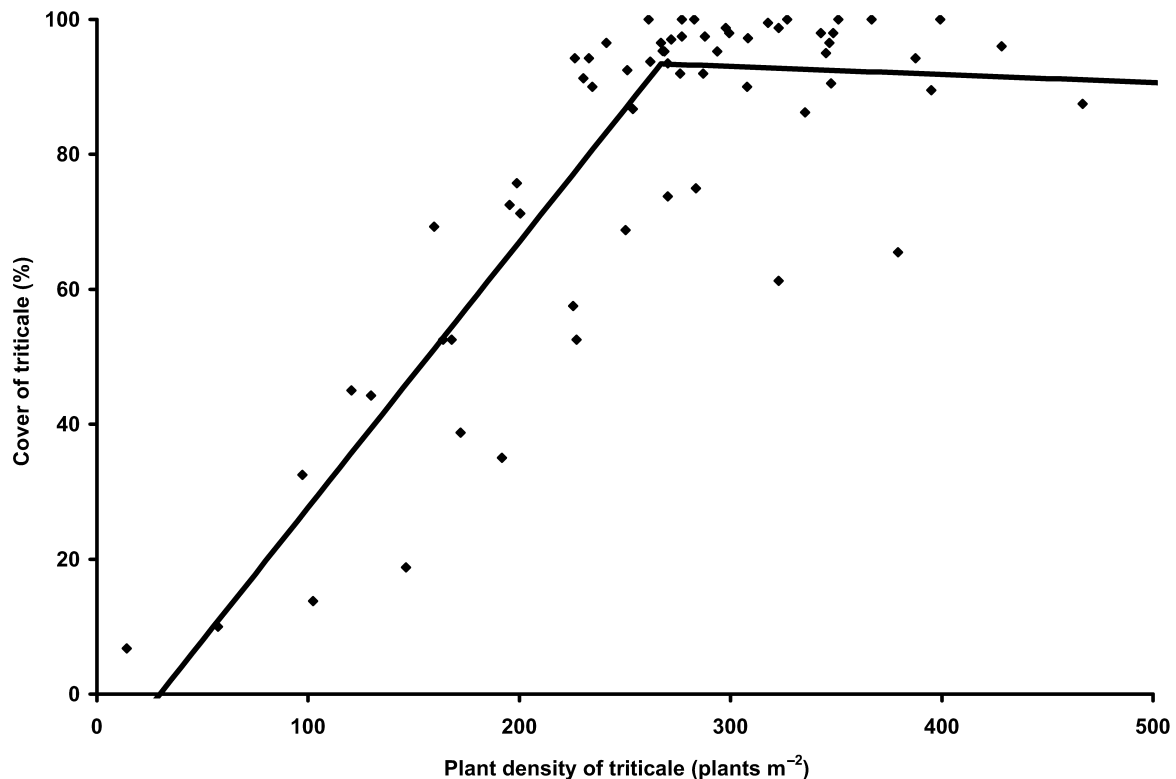


Figure 6 Relationship between plant density and cover of triticale. Points are the mean of four replicates. Values from the May harvest were not included. Lines ($Y = 0.394X - 11.8$ and $Y = -0.0119X + 96.6$) represent a single knot spline fit linear regression model from the NLIN procedure of SAS. Knot = 267 plants m^{-2} , $r^2 = 0.79$; $P < 0.001$.

and stand decline. As triticale varieties are known to exhibit high variability in tolerance to foliar diseases (Collin *et al.*, 1990; Arseniuk *et al.*, 1993), other triticale cultivars may be less affected by hot and wet conditions than the cultivar 'Trical 102' used in this study. Unlike many perennial, mixed-pasture species which can recover from stand degradation via recruitment from buried seed, and spread from rhizomes and stolons, annual small grains, such as triticale, have no capacity to replace lost individual plants. Increased number of tillers per plant would be a possible avenue to buffer plant loss but there was no relationship between tiller population and plant density found in this study (data not shown). As a result, low plant densities were associated with low DM yields. For example, plots sown in July and August tended to have higher plant densities and higher DM yields at the October harvest than plots sown in May and June.

Winter and spring responses

The increase in tiller populations frequently recorded during autumn is a typical response to cooling temperatures (Mozafar and Oertli, 1992; Bos and Neuteboom,

1998). The ability of triticale to maintain cover, plant densities and tiller populations over the late autumn and winter periods reflects the cold hardiness of winter triticale. These observations are consistent with expectations that triticale can support active growth in colder and drier conditions than mixed pasture species (Briggs, 2005). Indeed, early season growth of these triticale plots resulted in consistently superior DM yields relative to mixed pasture plots at the April harvests (Clapham *et al.*, 2008). It should be noted that native white-tailed deer (*Odocoileus virginianus* L.) are attracted to triticale in late winter when other food sources are limited. If not controlled, deer grazing can significantly reduce herbage mass of triticale and negate the potential benefit of early season production (Fedders and Clapham, 2004).

Unlike the relatively stable stand structure over the winter period, rapid changes in stand dynamics occurred during April as triticale progressed through its reproductive phase of development. Mean tillers $plant^{-1}$ and plants m^{-2} declined proportionately by averages of 0.40 and 0.24, respectively, between the April and May harvests across all years and sowing dates. Tiller losses in spring are known to coincide with main stem elongation with younger and smaller tillers

having an increased mortality rate (Davidson and Chevalier, 1990). Declines in tiller populations and plant density of triticale, however, were accompanied by an average 6.5-fold increase in tiller dry weight (data not shown) between the April and May harvests as stems elongated and the plants developed to the boot stage. This increase in tiller mass more than compensated for losses in plants and tillers. Plots harvested in both April and May exhibited on average a three-fold increase in yield between the 2 months. However, harvesting in April reduced DM yields in May of September-sown plots by an average of 0.58 relative to September-sown plots that were harvested only once in May. Yields of DM in May from previously uncut September-sown plots averaged 7960 kg ha⁻¹ while the total average combined DM yield of the September-sown plots harvested in both April and May was only 5081 kg ha⁻¹. Clapham *et al.* (2008) reported that mean annual cumulative yield for the six harvests of May-sown plots was similar to that of the September-sown plots cut only once in the following May. Annual cumulative yields from all other plots declined at later sowing dates which was associated with a reduced number of harvests.

Use of triticale

Rapid declines in plant density, such as occurred in most years for the May- and June-sown plots, resulted in reduced cover and DM yield. Rapid declines in plant density also occurred when hot and wet weather resulted in elevated plant mortality and limited growth and tillering of surviving plants. Seeding rates higher than those used in this study for early sowing dates may offset declines in plant density, cover and DM yield. This approach should be evaluated, however, as the benefits associated with higher seeding rates may be negated by higher mortality rates in the denser canopy.

Systems incorporating triticale paddocks with mixed perennial cool-season pasture may reduce the occurrence of shortages of herbage due to cold (Woledge *et al.*, 1990) and drought (Malinowski *et al.*, 2005) conditions. Such systems would be buffered by growth of triticale being predominant during periods of cool and/or dry weather and mixed pasture production being predominant during warm and wet periods. Clapham *et al.* (2008) provided detailed comparison of triticale and mixed pasture production using probability and risk analyses. Systems in the central Appalachian Highlands could be developed to utilize winter triticale in a variety of ways to buffer low herbage production from mixed, perennial cool-season pasture. Sowing of triticale in June would be beneficial if dry conditions limited DM production in August from mixed pasture.

Autumn and early spring grazing could be supplemented by August-sown triticale which could provide acceptable DM yields during October and the following April. Triticale yields from September sowing were consistently among the highest that were achieved at harvest in the following April. There may be less utility in October-sown triticale which had variable DM yields in the following April. Schwarte *et al.* (2005) reported similar findings in Iowa, USA where sowing in October resulted in reduced DM yields in the following spring compared to sowing in September. They reported that at least 300 growing degree days (base 4°C) were needed between sowing and 31 December for maximum spring production. Single harvests in May from September-sown paddocks could provide forage of high nutritive value for conservation as hay or haylage. Sowing in September with utilization in the following April and May could leave fields available for rotation with a summer annual crop. The consistent pattern of early and rapid spring growth provides opportunity for management options depending upon herbage requirements. Triticale swards can provide an early season source of herbage that could be rotationally grazed throughout April and early May, grazed in early April and then reserved for a haylage harvest or reserved completely to maximize haylage production. Triticale could also make an excellent break crop by providing a short-term source of herbage during the renovation process from an endophyte-infected tall fescue pasture or ageing alfalfa field to another perennial-based forage stand.

This study suggests that pasture systems that combine areas of mixed cool-season perennial pastures with areas of winter triticale are buffered against weather-induced declines in herbage production. The buffering effect is driven primarily by tolerance to cold and drought (triticale) or tolerance to high soil moisture contents (perennial, cool-season grasses). Productivity is related to tolerance of adverse environmental conditions, and in triticale to plant survival and the degree of tillering and the resulting stem population.

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